Dynamic Voltage Restorer Using AC Chopper for Distribution System

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Abstract

This paper deals with modelling and digital simulation of AC chopper based Dynamic Voltage Restorer (DVR). The control of DVR that injects a voltage in series with a distribution feeder is presented. DVR is a power electronic controller that can protect sensitive loads from disturbances of voltage fluctuations in supply system. It is observed that DVR can regulate the voltage at the load. Circuit model is developed for the single phase model and the same is used for simulation studies. It is tested for different capacity loads.

Keywords: Dynamic Voltage Restorer (DVR), Simulink, Series Compensation, AC chopper

I. Introduction

A power electronic converter based series compensator that can protect critical loads from all supply side voltage disturbances other than outages is called a dynamic voltage restorer (DVR). The restorer is capable of generating or absorbing independently controllable real and reactive power at its AC output terminal. This device employs AC chopper or AC voltage controller structure. It injects output voltages in series with the distribution feeder at the given load location. In 1996, Westinghouse Electric Corporation installed world’s first dynamic voltage restorer in 12.47kV substations in Anderson, USA. This was installed to provide voltage correction to an automated rug manufacturing plant [1, 2].

This paper extends the concept of dynamic voltage restorer to maintain the load voltage near the rated value. It can also perform the primary functions of the restorer, i.e., to protect the load from temporary sag and swell. This device is a DVR. The output of the chopper voltage will inject to the distribution feeder through the injecting transformer in order to maintain the constant voltage. For the control operation of DVR designs the on-off control of ac voltage controller with different duty cycles (from 10% to 99.99%).

The actual implementation of the DVR using chopper raises additional issues of harmonics. The filter is used to eliminate these harmonics. The operation of ac chopper is given by [3].

The above literature does not deal with the modelling of DVR system using simulink. In this work, an attempt is made to model and simulate the DVR system using Simulink.

2. Problem Formulation

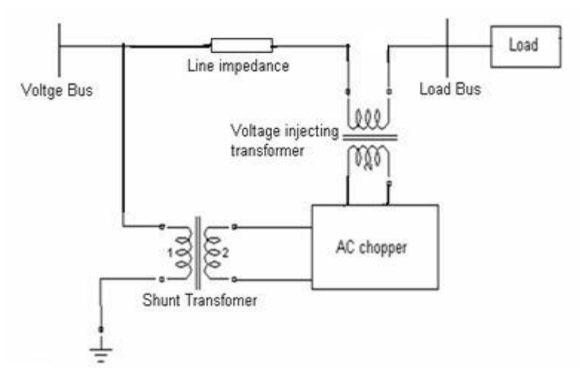


Fig.2.1: Block Diagram of DVR

A DVR is a recently proposed series connected solid state device that injects the voltage in to the system in order to regulate the load side voltage. It is normally installed in a distribution system between supply in feeder at critical load location [4].

The general configuration of a DVR consists of a shunt transformer, AC chopper, injection/booster transformer [5] and a harmonic filter as shown in fig2.

The voltage at load terminal (V_L) is equal to sum of supply voltage (V_{Supply}) and the output voltage of the chopper (Vinjected).

VL= VSupply $^+$ Vinjected

The basic function of the injection transformer is to increase the voltage by injecting a series voltage derived as output of the chopper while isolating the DVR circuit from the distribution networks.

The rating of the injection transformer is an important factor while deciding the DVR performance, since it limits the maximum compensation ability of the DVR. Further the leakage inductance of the transformer brings to a low value to reduce the voltage drop across the transformer. In order to reduce the saturation of the injection transformer under normal operating conditions it is designed to handle a flux, which is higher than the normal maximum flux requirement. The winding configuration of the injection transformer mainly depends upon the upstream distribution transformer.

For any type of load (i.e. R, RL and RC) the supply voltage is same because there is no voltage drop due to source impedance except the drop in line impedance.

3. Simulation Results

A typical system data is given in table1 for a radial feeder connected to a load along with two transformers and filter. Digital simulation is done by using Simulink and the results are presented here .DVR using AC chopper is shown in Figure 3a. The output of the Chopper is injected into line through a series transformer. The voltage across load for different duty cycles is shown in Figure 3b. FFT analysis for the output voltage is shown in Figure 3c. THD is 30.17% for 90% duty cycle. DVR system with LC filter is shown in Figure 3f. Injected voltage and the voltage across loads for ±25% of the source voltages for different duty cycles are shown in Figure 3g and 3h.

FFT analysis for the output voltages is shown in Figure 3i and 3j. THD Reduces to 0.01%. Thus the harmonics are reduced from 30.17% to 0.01%.

Table1: System Data

SUPPLY VOLTAGE	6350V
LINE IMPEDANCE	1+j0.001Ω
SHUNT T/F TURNS RATIO	1:5
INJECTING T/F TURNS RATIO	1:1
FILTER INDUCTANCE	7µH
FILTER CAPACITANCE	0.09046F
LOAD RESISTANCE	635Ω

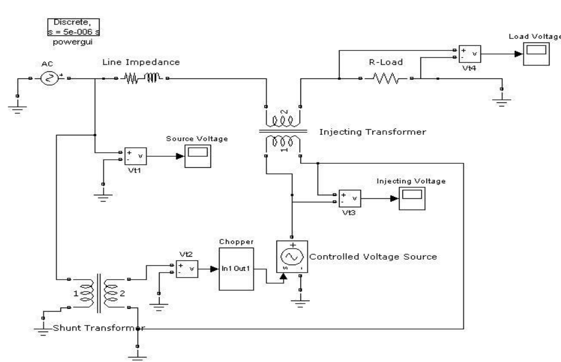


Fig.3a: DVR Circuit without Filter

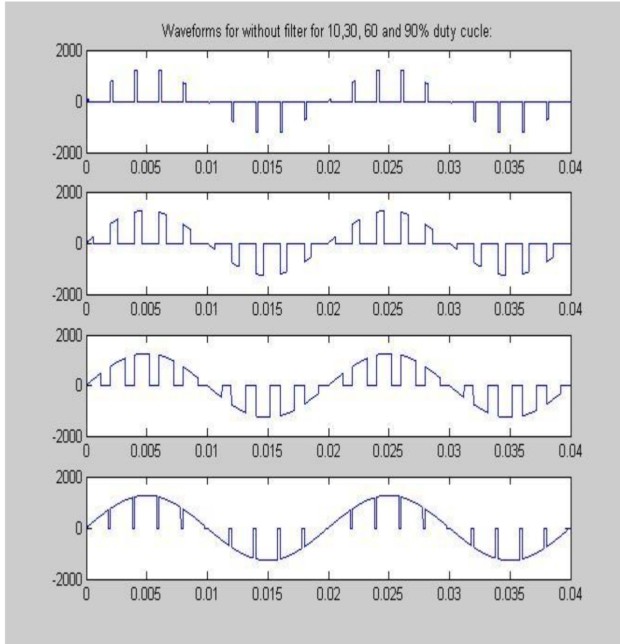


Fig.3b. Waveform of Load Voltage with Out Filter

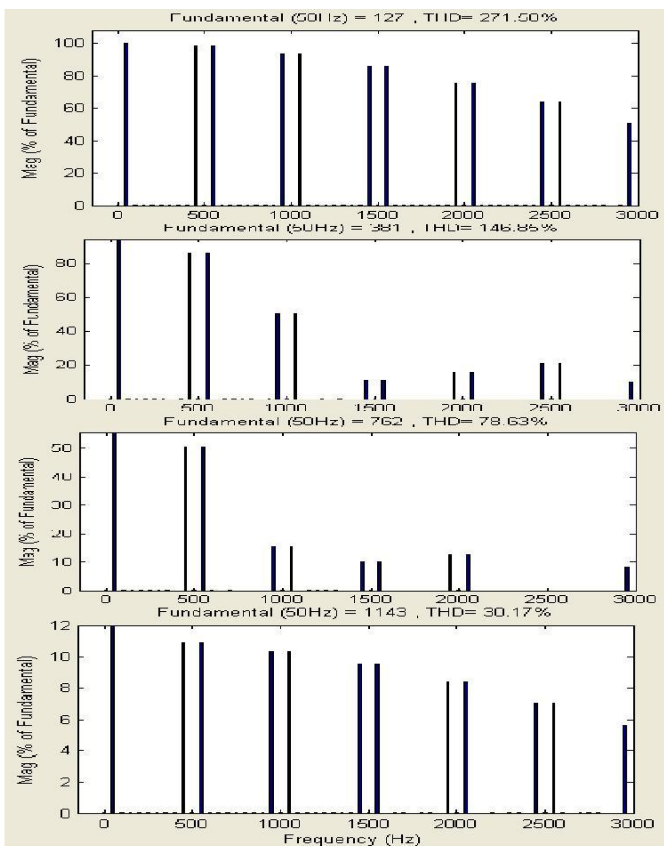
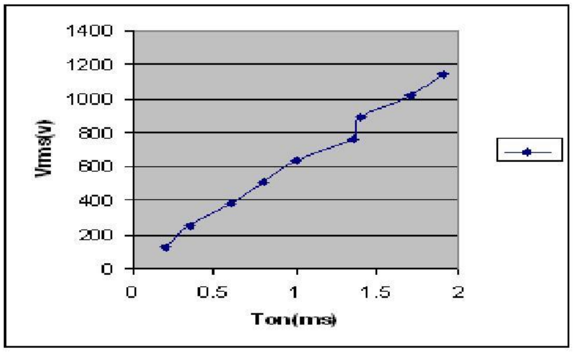


Fig.3c. FFT Analysis for Harmonics Load Voltage without Filter

The characteristics of on time and off time versus rms voltage as shown in fig 3d and 3e.



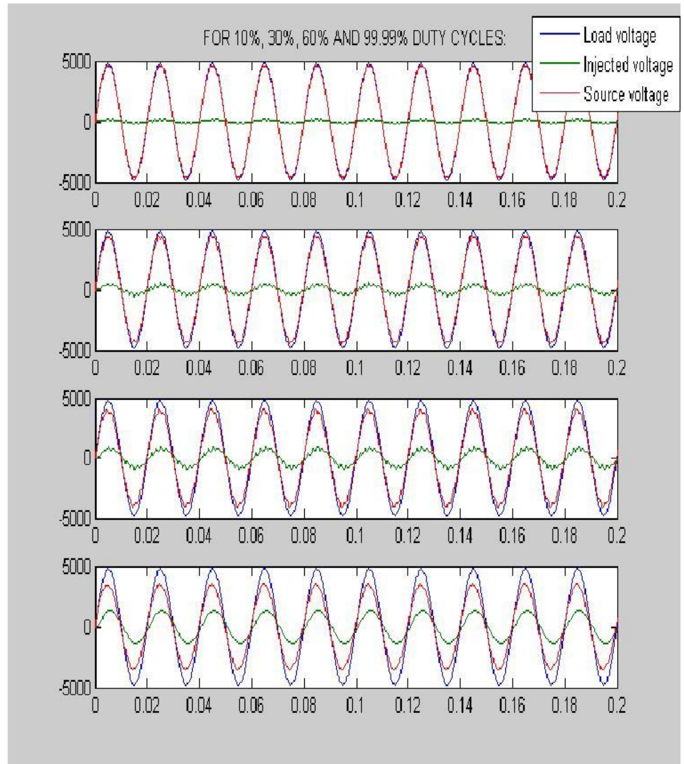


Fig.3d: Ton versus Vrms Characteristics

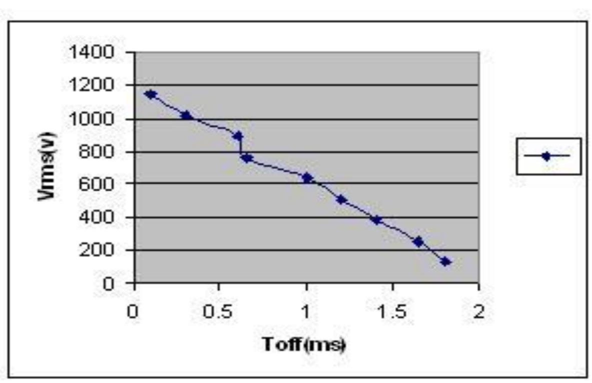


Fig.3e: Toff versus Vrms characteristics

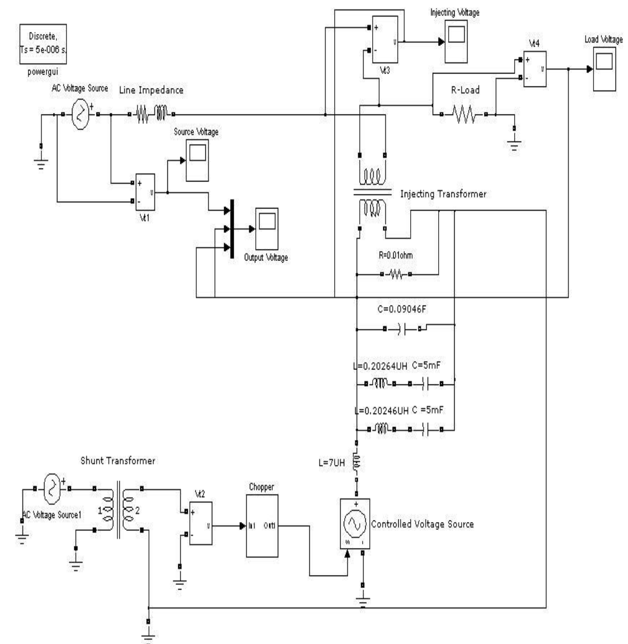


Fig.3f. DVR Circuit with filter

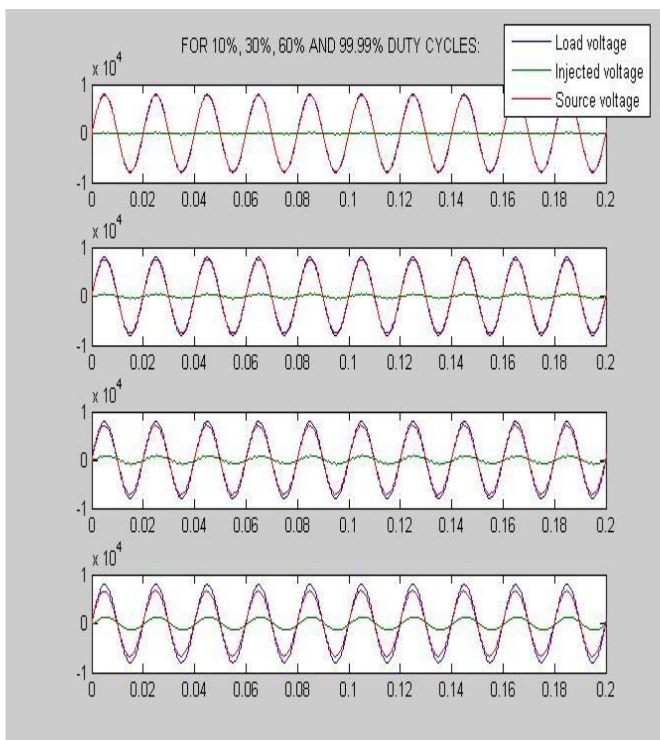


Fig.3h: Waveform for Input Voltage is +25% (7937.5V)

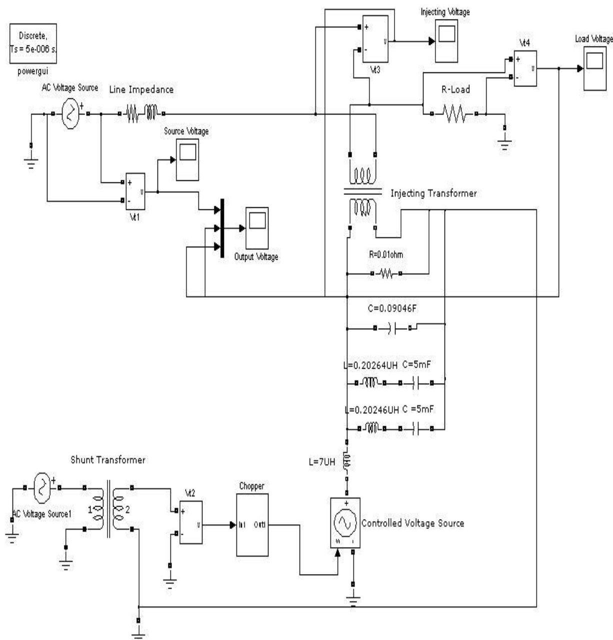
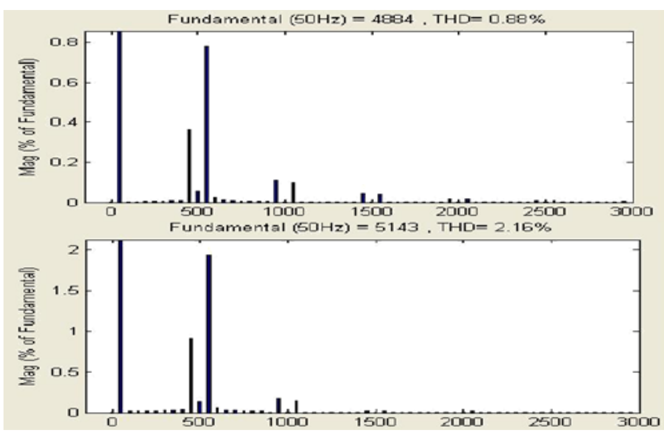


Fig.3f. DVR Circuit with filter



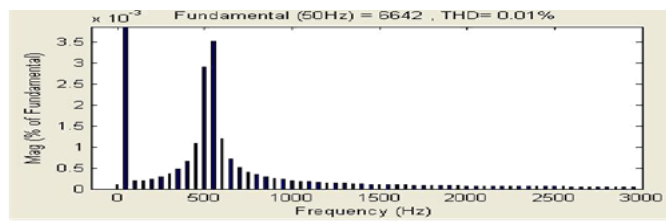
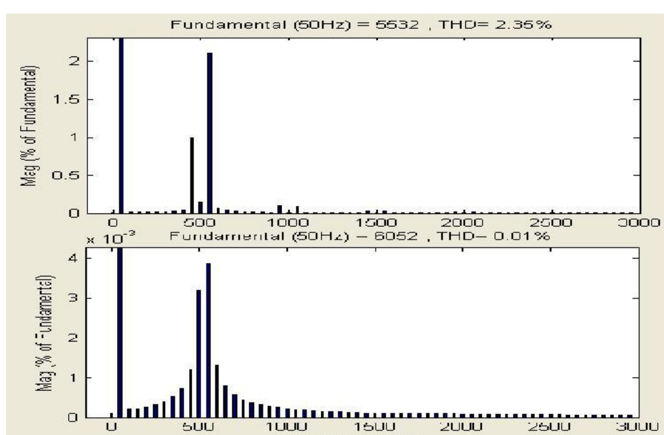
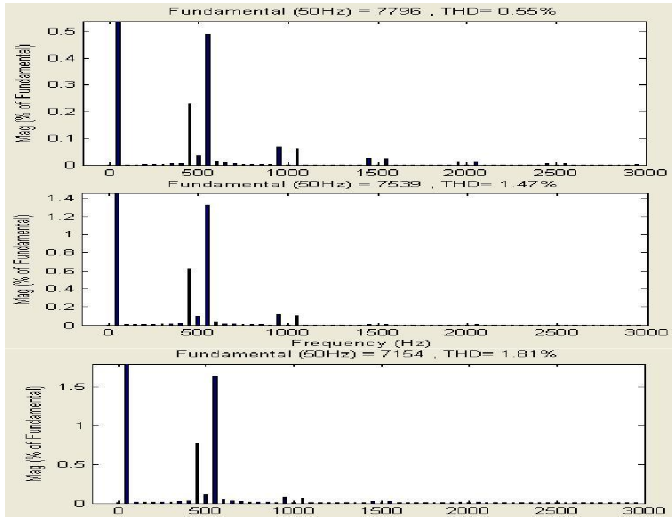


Fig.3i: FFT Analysis -25% of Input voltage **Fig.3j: FFT Analysis -25% of Input voltage**

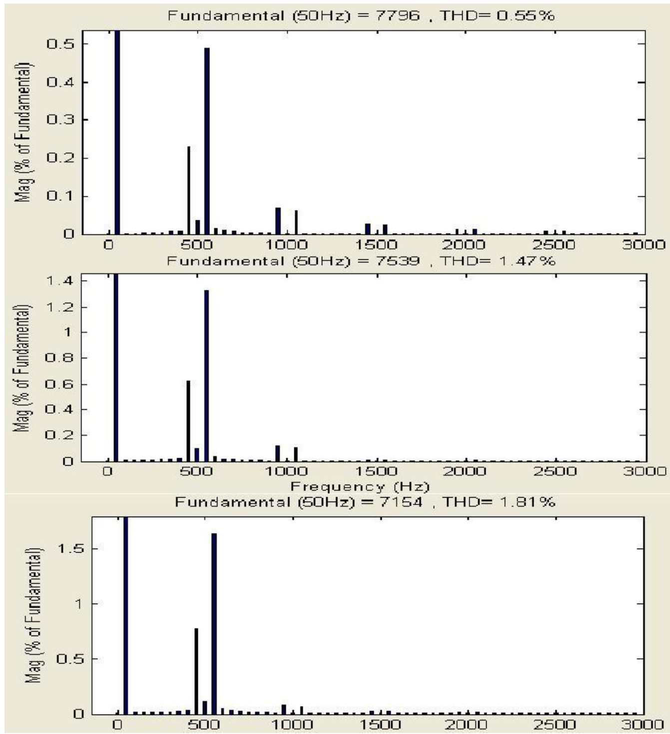




The results are given in Table2 for supply voltage variation from +25% to -25% above the rated voltage in steps of ±5%. The corrected voltage across the load, variation and the THDs are shown for each case.

Table2. Look-up table

Duty Cycle (%)	**Supply Voltage(V) (6350V)**		**Load Voltage(V)**		**THD (%)**
	Total voltage at supply	Voltage injected in Percent-tage	Total voltage at load	Load variation in Percen-tage	
99.99	7937.5	+25	6642	+4.6	0.01
80	7620	+20	6581	+3.6	1.23
50	7302.5	+15	6648	+4.69	2.05
30	6985	+10	6588	+3.74	1.68
5	6667.5	+5	6528	+3.8	0.33
99.99	4762.5	-25	6052	-4.6	0.01
80	5080	-20	6108	-3.8	1.85
50	5397.5	-15	6036	-4.9	2.26
30	5715	-10	6094	-4.0	1.82
5	6032.5	-5	6087	-4.1	0.36



4. Conclusions

The load voltage is controlled to within a maximum value of 4.69% the THD within 2.05%.The use of AC chopper for voltage restoration is much simpler then to previous used DVR schemes. The authors feel that this method is for the first time used in DVR schemes .It is the authors' original contribution. The work will be extended to 3-phase system and reported later.

References

N.H. Woodley, L. Morgan and A. Sundaram, "Experience with an inverter-base dynamic voltage restorer," IEEE Trans. Power Delivery, Vol. 14, No.3, pp.1181-1185, 1999.

Lei B.H., Choi S. S., and Vilathgamuwa D.M.: Design considerations on the line-side filter used in the dynamic voltage restorer.

IEE Proceedings — Generation, Transmission, and Distribution, vol. 148, pp. 1–7, Jan. 2001.

MOZDER, A. JR. – BOSE, B. K., Three-Phase AC Power Control Using Power Transistors, IEEE Trans. Ind. Appl., IA-12 (1976), pp. 499–505.

Chan, K., 1998. Technical and performance aspects of a dynamic voltage restorer. In IEE Half Day Colloquium on Dynamic Voltage Restorers- Replacing Those Missing Cycles, pp: 5/1-525.

Kularatna N.: Power Electronics Design Handbook: Low-Power Components and Applications. Boston: Newnes, 1998.